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Iron-ore Deposits in the Kosna Ore Field, Trgovska Mountain, Croatia

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Ključne riječi: Parageneza, Način pojavljivanja rudnih pojava

U radu je dat prikaz rudarske djelatnosti u paleozoiku područja Kosna gdje se rudarilo na limonite i bakronosne ankerit-siderite. Dat je detaljniji opis načina pojavljivanja rudnih pojava, njihova parageneza i kvalitet rude.

Key words: Paragenesis, Mode of occurrence

The paper gives an account of minig operations in the Palaeozoic of the Kosna district, where mining was conducted for limonite and copper-bearing ankerite-siderite deposits. A detailed description is given of the mode of occurrence, the paragenesis and the quality of the ores.

Introduction

The Kosna ore field is situated immediately to the east of the copper-bearing siderite deposits of the former Katarina, Svinjica and Gradski potok mines recently described in a paper by Jurković (1989). The area is bounded to the north by the Sredorak potok (a tributary of the Šerbule potok), on the north-east by the Šerbule potok (a tributary of the Velebit potok), on the south-east and south by the Velebit potok, and on the west by a line running from north to south across Kosna Glavica (+381 m) and extending to the hamlet of Stambolije on the northern bank of the Velebit potok, covering a total area of 4 km^2 (Fig. 1).

The area consists exclusively of Upper Paleozoic Carboniferous sediments: shales, siltites and graywacke sandstones (Devidé-Neděla, 1953). In dolomite near the village of Kosna, SW of level +247, Milanović (1982) detected Moscovian (Upper Carboniferous) of the Beresella erecta type. Occurrences of limestones and dolomitic limestones were also noted in the valley of the Ilića potok as intercalations of varying thickness in shales and siltites. The series of sediments runs generally in a NW-SE direction, with a dip of 40–60° towards the SW, but there are considerably steeper gradients resulting from major tectonic dislocations.

History

There are a number of small to medium mineral deposits in the Kosna ore field: Kosna Vinogradina (no. 42 in Fig. 2), Julius (43), Kosna (44, 45, 46), Barbara (47, 48) and Ilića potok (49). Occurrences are also found in the former ore fields Henrikus (Fe), Alojs (Fe), Julius (Cu), Alojs Rikard II (Fe), Barbara (Fe) and Ilića potok (Fe).

Wojtanek's minig map (1772) shows the Kosna Vinogradina and Ilića potok ore deposits in the Kosna district. The Kosna and Barbara limonite mine was opened in 1794, and in 1804 a small blast furnace for smelting the ore began to operate in Kosna. On Szedelmy's map (1845) the Kosna mine was opened with three horizons, while there were six sets of exploratory workings at Ilića potok. According to Lipold's data (1855), the Julius copper mine was opened and in production, and it continued in operation until 1870. Then the extraction of iron ore was resumed in Kosna and Kosna Vinogradina (Hauer, 1870). By 1897 only the Barbara and Ilića potok mines were still operating (Zloch, 1897). Reuter (1910) writes that mining was resumed in 1901, for copper ore in Julius and Kosna, and for iron ore at the other sites. In 1913 all mining operations ceased in Trgovska gora (Papp, 1919). In 1937/38, 2,100 tons of ore was gleaned from the old dumps and conveyed to the blast furnace at Bešlinac. In 1952, prospecting was resumed, but yielded no results and was soon discontinued (Jurković, 1953; I.G.I., Šinkovec, 1968).

Description of the ore deposits

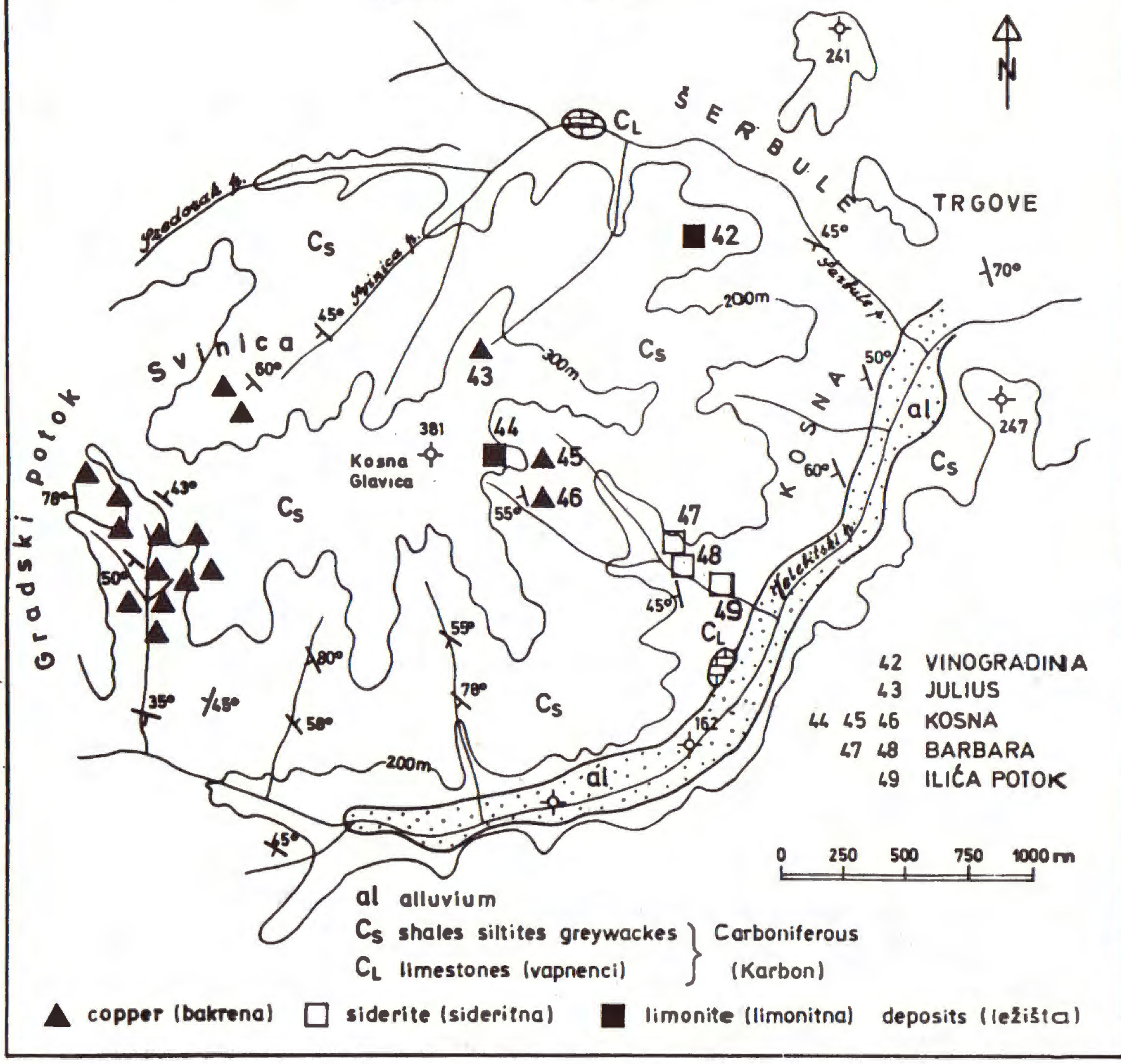
Stara Vinogradina or Kosna Vinogradina (42) is located west of the northernmost houses of Kosna village, on the lower reaches of Šerbule potok before its confluence with the Velebit watercourse. The ore deposits are at level +240 m, about 80–100 m above the level of the Šerbule brook, within the Henrik ore field.

Three deposits of ore are marked on Wojtanek's map (1772), running N-S, with a dip to the west. Szedelmy (1845) calls this site Kosna Vinogradi. Hauer (1870) records that it is a limonite deposits 400 m long, with a lode up to 3 m thick in places. The mineralisation of Kosna Vinogradina is referred to by Papp (1919), Turina (1933), Granigg (1934) and Tućan (1947), but without any detailed data, since the old workings had been demolished. In 1938, 100 tons of limonite from the old spoil heaps was despatched to the blast furnace in Bešlinac. In 1952, the old workings were partly cleared and geologically surveyed. Magnetometric records were also made, but with negative results (Jurković, 1953; I. G. I., 1968).

An outcrop of hard limonite about 1–2 m thick runs E-W, with a dip southwards. In an easterly

Fig.(Sl.)1 ORE DISTRICT KOSNA

RUDNO PODRUČJE KOSNA



direction it forks and peters out, while, towards the west, it also quickly peters out. Its exposure extends for 25 m. The shales in which the ore was found ran NW-SE, with a dip of 50° towards NE. An adit was run from the north side of Glavice, about 10 m below the outcrop and extended for 38 m, but it traversed nothing but limonitized slates with two thin intercalations of limonite. Work was stopped because of these poor results.

The **Julius** mine (no. 43) is located about 500 m NNE of level +381 m in a narrow gorge, through which one of the minor tributaries of Šerbule potok flows.

Lipold (1855) reports the opening of Julius, and reckons that its promise justifies further prospecting. In 1870 operations were discontinued because of a fall in the price of copper. A renewal of the old workings and a resumption of production is reported by Reuter (1910), who emphasises the large quantity of minegas in the black shales where the ore beds are located. Papp (1919) also refers to Reuter's findings. The pit was closed down in 1908. Aleksijević (1922) states that the ore beds were opened up by means of an adit 200 m long, running NW alongside the deposits. The ore was followed in depth by means of two very steep inclines at an angle of 80° in a SW direction. The ore consisted of siderite with a sprinkling of chalcopyrite. Turina (1933) reports that the lode was no more than 5–10 cm thick, while Steiner, following Tolić (1948) quotes a thickness of 0.5–0.7 m, and Holzinger 0.3–0.6, with cover of 48 m.

Ore extracted from the higher grade parts of the deposits contained, according to Reuter (1910): 4.68% Cu, 13.11% SiO_2, 0.02% Al_2O_3, 2.12% CaO, 1.54% MgO, 0.08% Pb, 37.16% Fe, 41.01% heat loss and H_2O^{-105}, 0.28% S. It contained no BaO, Mn or Sb. One sample analysed in 1905 contained 5.21% Cu (Aleksijević, 1922).

Microscopic analysis of ore samples (Jurković, 1953):

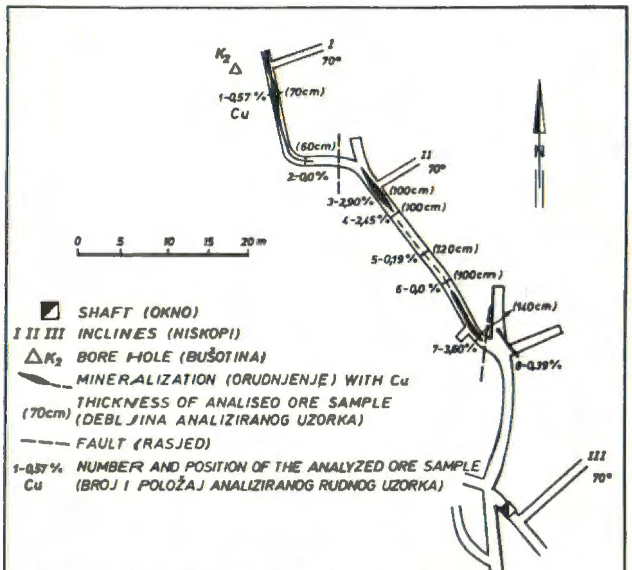


Fig.(SL) 2 LOWER KOSNA ADIT (DONJA KOSNA POTKOP)

Siderite is the main ore mineral in the paragenesis of the primary zone of the Julius ore bed. It is coarse-grained, more or less oxidised into »red spar or Braunspat« in the form of submicroscopically fine *hematite* dust. It contains very sparse relict grains of *pyrite I* and *quartz I.* Siderite has been replaced to varying degrees by minerals of a younger generation. For the most part it is *quartz I* which replaces siderite along the rhombohedral cleavage plane, micro-fissures and cracks, or else forms frontal nests and networks of veinlets within the siderite mass. It is tectonically dislocated and cataclased. It embodies *pyrite II,* which is markedly cataclased and in part milonitised. It is weakly anisotropic, probably because of the presence of arsenic or nickel in the lattice. The main sulfide mineral is *chalcopyrite,* which replaces both siderite and pyrite. It contains relict grains of *sphalerite.*

The quantity of hypergenic minerals increases towards the upper parts of the bed, where oxidation processes are prevalent. The most abundant of them is *goethite,* secondary minerals are also *lepidocrocite* and *malachite,* while *covellite* and *chalcocite* were noted in the transitional zone.

The Kosna Mine (44, 45, 46)

The mine is located on a ridge to the east of level +381 m. It comprises open-cast workings and three adits at different levels. It is not clearly linked with the Julius ore bed.

As early as 1772 (Wojtanek) three ore deposits were known, running N-S, with a dip to the west. The Trgovi Iron Works began to work the ore in 1794, and in 1804 a smallish blast furnace began to operate in Kosna. Szedelmy (1845) marks adits on three levels at Kosna: Lower, Middle and Upper Kosna. In the period down to 1870 mining was concentrated on copper ore, while the extraction of iron ore was on smaller scale. According to Hauer (1870) work on limonite was resumed, because the deposits, extending for 400 m and 12 m thick in places, were considered promising. Operations ceased in 1897, but were resumed in 1901 (Reuter, 1910). According to this author, the ore bed was explored to a length of 200 m and a depth of 40 m. Half of the prospected length was productive, and the limonite was up to 3 m thick. Copper ore was also extracted. According to Papp (1919), there was a major inflow of underground water into the deeper parts of the mine. We have more detailed information about the mine from Aleksijević (1922), who reports that it consisted of adits at various levels, together with a number of saps and inclines, and two ventilation shafts. The length of the workings was 230 m, running in a N-S direction. The lowest adit was at +256.8 m, while the uppermost was at +341.1 m. The slope of the lode was to the west, it was 3 m thick. At the upper levels the ore consisted of quartzitic limonite, while at the lower levels it consisted of siderite with chalcopyrite or quartz with chalcopyrite, with increasing quantities of pyrite and intercalations of shale. Turina (1933) took over previous data, mentioning that the dip in the ore bed is 65° to the west, and that ankerite features in the lower parts. Granigg (1934) reports only one deposit round level +381 m, giving a negative assessment. In 1937/38, 2,000 tons of ore was removed from the dumps. Limonite in Upper Kosna, and siderite with chalcopyrite in Middle Kosna are also mentioned by Tućan (1947). In the report by Marić et al. (1951) there is a relatively brief account of Kosna. A detailed report, with a critical review of the older data is to be found in an article by Jurković(1953). In the report by I.G.I. (1968) there is a brief reference to Kosna, from which we might quote that 40,000 to 50,000 tons of limonite were extracted from the deep oxidation zone, with a note to the effect that the limonite in the surface parts was 1–3 m thick, and only 0.5 m thick in the deeper parts. There is siderite and ankerite in the primary zone, but they were only partially exploited, because the copper content was too low and the deposit relatively thin.

When the old workings were cleared, the following results were revealed (Jurković, 1953): on the *Open-cast site* in the immediate vicinity of hill +381 m, at an altitude of +341 m, a thick outcrop of quartzitic limonite was visible which had been left after the higher grade part of the deposit had been extracted.

The Upper Kosna adit (44) was located 20 m below the open-cast workings at level +321 m. Hard limonite with skeletal veins of quartz up to 3 m thick. Analysis showed Fe content ranging from 28.6% to 60.1%, with SiO_2 content of 5.3% to 38.1%. Limonite with excessive quartz was no sent to the blast furnace, but left in the pit.

The Middle Kosna adit (45) is on a level 30 m lower down, i.e. at +290.1 m. The gallery passed in part through limonite, but ran for the greater part of its length through siderite with quartz and chalcopyrite. With the opening of this adit, the mine was converted from iron to copper ore. The Cu content in the productive part of the gallery ranged from 3.3% to 10.6% Cu. The ore deposits follow an irregular course, varying in thickness. The content of siderite, quartz and chalcopyrite varies considerably, according to the run and the dip of the ore bed. Numerous tectonic dislocations may be observed.

The Lower Kosna adit (46) is a further 24 m lower than the Middle Kosna adit and is situated at level +266.5 m. Access was from the southern side of the Kosna ridge, from the sloping flank of the valley of the Ilića brook. The adit ran northwards, intersecting the ore bed at 80 m and continuing in the direction of the mineralisation. (Fig. 2) At first, this direction was NW, later NNW. The lode is interrupted by faults at a number of points and is considerably dislocated, signs of compression, crushing and crumbling of the ore may be noted. The thickness of the bed is exceptionally variable, ranging from mere traces in »Letten« (clay bed), through several centimetres to 1 m at most. In the richer part of the bed the adit is linked by three shafts to the Middle Kosna adit. Mining was conducted only in the richer part of the deposit, on a seam declining about 70° to the SW. The poorer or sterile parts of the deposit were left. Alongside shaft no. III an attempt was made to explore the downwards extend to the lode by means of a shaft sunk to a depth of several metres, but the results were negative. Analyses carried out in 1952 after the old workings had been cleared (Tables 2, 3) revealed that certain parts were productive. A test bore-hole sunk from the surface in 1952 only penetrated a thin ore-bearing zone with a little quartz, siderite and negligible amounts of pyrite and chalcopyrite. Geophysical researches carried out at the same time yielded no positive results.

From an analysis of data relating to the old mine-workings, chemical analyses and microscopic analysis of samples taken from the Lower Kosna dumps, we draw the following conclusions. The Kosna ore deposits are a »Lagergang« concordantly intercalated in shales with thin strata of siltites and subgraywacke sandstones. The ore bed runs NW-SE, veering in places towards NNW or WNW, and with a general dip of 70° towards the SW. The thickness of the seam is very variable, ranging from a few cms to 3 m, being thicker on the upper horizons and becoming thinner as we proceed downwards. It is tectonically very dislocated through faults, crumbling and pressure. The oxidation zone with more or less quartzitic limonite makes its appearance from an outcrop at +341 m down to a level of +290 m, i.e. to a depth of 50 m, a result of the lie of the land where the ore bed makes its appearance above the Ilića potok and its valley. bearing in mind that the deposits are open to depth of +266 m, it may be seen that 2/3 of the downward extension was in the oxidation zone, and no more than 1/3 in the primary zone. Besides, the lower third of the ore bed was mostly unproductive on account of its dwindling thickness and the low content of chalcopyrite in most of this sector. The greater part of the productive area of the ore bed has been worked out.

Microscopic analysis of primary ore from the Lower Kosna adit spoil-heap gave the following results:

Relatively coarse-grained crystalline *siderite* is the main mineral in the paragenesis. It is transformed to a greater or lesser degree into »red spar« by oxidation into sub-microscopic *hematite* dust, which gives rise to brown and reddish internal reflexes. The siderite is silicified to a considerable extent. *Quartz* partly replaces siderite, either forming small, nest-like masses frontally, or else complexes of microveins or veinlets pervading the siderite in skeletal form. *Pyrite* and *chalcopyrite* also replace siderite, taking advantage of cleavage planes, fissures and the edges of intergranular spaces in the siderite. The other sulfides, such as *sphalerite*, are purely secondary constituents. In the primary zone hypergenic minerals are very scarce: *covellite, chalcocite, malachite, goethite, lepidocrocite.*

Table 1

Chemical analyses of limonite ore from the Kosna mine

	1	2	3	4	5	6	7
SiO_2	21.06	27.50	5.30	38.05	11.34	3.70	25.48
Al_2O_3	3.25		24.10	9.88	4.26	1.23	0.36
CaO					0.84	0.30	0.36
MgO					0.10	0.20	0.07
Fe_2O_3	59.60	53.53	65.34	39.04	75.59	88.70	62.96
Fe	41.68	37.44	45.70	28.60	52.87	62.04	44.04
MnO	3.43		1.66	0.77	0.94	0.87	0.88
Cu	0.57						
S	0.11		trace	0.03	0.12	0.04	0.04
Lost of ignition	11.14				7.80	5.10	0.20

The analysis under 1) dates from 1902, 2) and 3) from 1905, 4) from 1906 (Aleksijević, 1922). The analyses under 5) and 6) are from 1910 (Reuter, 1910), the analysis under 7) is from 1940, New Kosna adit (Tućan, 1947).

Table 2

Chemical analyses of primary, sulfide copper-bearing ores (Kosna)

SiO_2	Al_2O_3	CaO	MgO	MnO	FeO	Cu	S	Lost of ignition
58.86	5.98	5.10	0.75		13.30	3.31	9.27	5.43
27.85	4.15	0.60	0.10	0.54	24.60	10.65	27.37	4.26

By recalculation of the analyses of the rich ore under no. 2 in terms of mineral constitution, basing the composition of the shale in which the ore body is located on illite and quartz, we obtained the following results: 10.26% illite, 22.96% quartz (in the ore and in the shale), 2.73% (Ca, Mg, Mn, Fe) CO_3, 30.96% $CuFeS_2$, 31.02% FeS_2 and 1.54% $H_2O^{+105°}$.

Partial chemical analyses for Cu and Fe in the Lower Kosna adit (Fig. 2). Worked out in 1952 in the Sisak Iron Works, are shown in Table 3.

Table 3

Partial chemical analyses of Fe and Cu

	1	2	3	4	5	6	7	8
Fe	9.22	4.89	5.46	5.33	5.46	3.87	3.76	19.02
Cu	0.57	–	2.90	2.45	0.19	–	3.60	0.39

Barbara Mine (no. 47, 48)

This mine consists of an open-cast and two adits, Upper and Lower Barbara. It is located on the northern slopes of the Ilića potok valley, about 0.5 km upstream from its junction with the Velebit watercourse.

The earliest data derive from Wojtanek(1772), who marks 4 ore deposits running N-S with a dip to the west, of which 3 had been prospected by means of adits. In 1794 the »Trgovi Iron Works« opened the Barbara Mine. On Szedelmy's map (1845) there were six exploratory or production sets of workings on the Ilića potok (Ograde), one of them close to the Velebit potok. Zloch (1897) reports that in the Kosna field only the Barbara

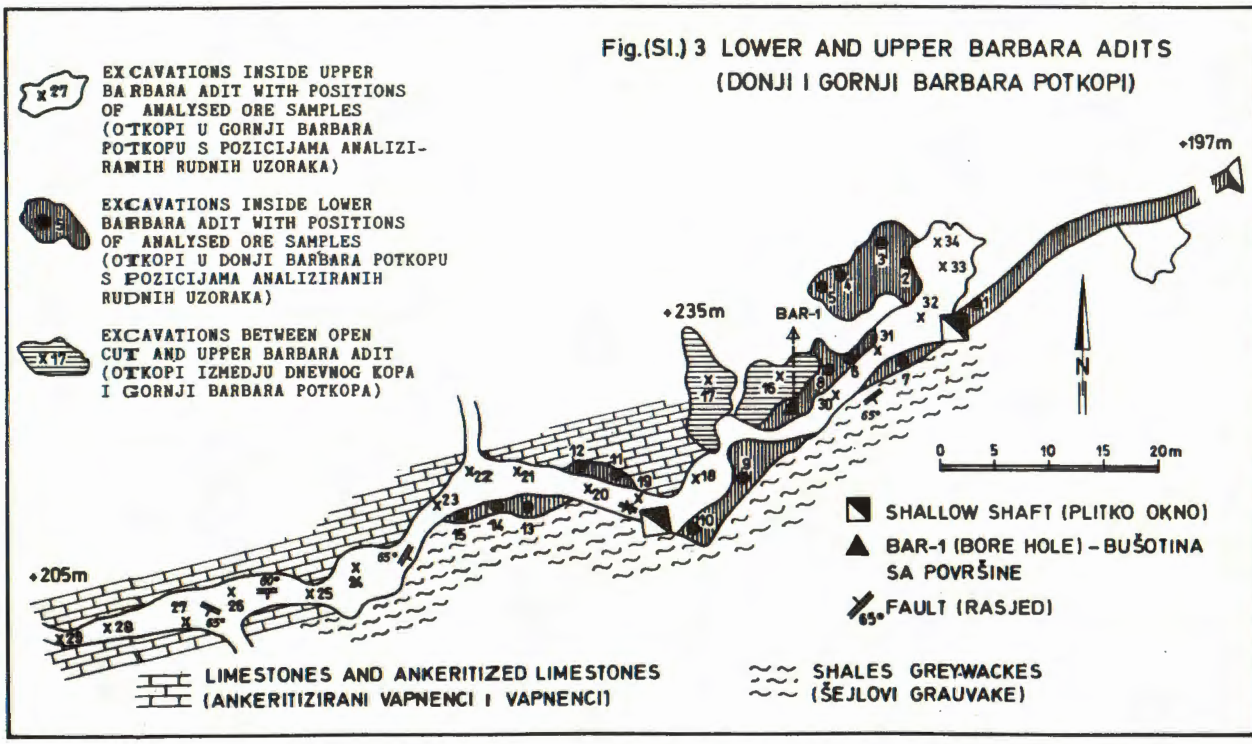


Fig.(Sl.) 3 LOWER AND UPPER BARBARA ADITS (DONJI I GORNJI BARBARA POTKOPI)

mine was working on the Ilića potok, with three sites. The upper adit intersected 4 m of limonite at a distance of 60 m and followed the course of the ore bed for about 75 m, when it entered black shale. It was situated about 20 m below the Barbara open-cast. The Lower Barbara adit cut through an 11 m thick siderite ore body, where old and more recently extended workings are located, in part very inefficiently excavated. At the bottom of the Ilića potok valley, about 40 m below Barbara there were exploratory workings which encountered siderite at 60 m. The Barbara reserves amount to 62,500 tons. A small adit 180 m SE of the Barbara mine at level +180 m intersected a lode of siderite 1 m thick. In their papers Reuter (1910) and Papp (1919) refer to the pre fileds Barbara (Fe) and Ilića potok (Fe). Aleksijević (1922) reports that the workings began with an open-cast site and were continued with the adits Eduard Glücksbau, Upper Barbara, Lower Barbara, Althoffnungsbau and prospecting between Glücksbau and Althoffnungsbau. The difference in altitude was 25 m, and the transport of the ore was effected via the Eduard Glücksbau adit. An analysis from 1939 gives 50% Fe and 0.9–1.0% Mn in limonite and 30–40% Fe and 0.5% Mn in siderite. According to Holzinger (oral comm.) about 20,000 tons of siderite was left in Barbara, which would yield 46% Fe and 2% Mn on smelting. In 1938 1,000 tons of siderite was removed from the dump for the blast furnace in Bešlinac. Tolić (1948) and Marić et al. (1951) also refer to occurrences in Barbara and Ilića potok. In the report by I.G.I. (1968) Barbara is considered to be an ankerite ore field. It feature irregular strata and lenses of limestones and dolomitic limestone in shales and sandstones with 4–35% Fe, along with some quartz and sulfides, for the most part oxidised.

In 1952 the Barbara workings were cleared; this included the *open-cast site* which is located at levels +235 to +236 m, the *Upper Barbara* adit (47) at +205 m, by means of which ore was extracted from beneath the open-cast workings, and the *Lower Barbara adit* (48) at level +197 m, 170 m long and orebearing to a depth of 75 m. From Lower Barbara an incline 8 m long led up to Upper Barbara (Fig. 3). Only the siderite parts of the ore body were worked, the ankerite and limestone being left. The excavated area has the very irregular shape of chambers of varying size. It is estimated that about 50,000 tons of siderite and limonite were extracted. In the western sector of the ore field, in the Lower Barbara adit, a major fault was encountered. An attempt was made to explore the extent of the ore body beyond the fault by boring. Three bore-holes were made, all of which confirmed the fault, but did not locate any extension of the lode. *Bore-hole Bar-1* was located on the open-cast site at level +236 m. The bore-hole is vertical. At 46.5 m it entered shales, having passed through the open-cast zone and underground chambers, having gone through siderite and ankeritised siderite between 26.0 m and 46.5 m. At +189.5 m, i.e. 7.5 m below the level of Lower Barbara it emerged from the ore bed. *Bore-hole Bar-2* was a vertical pit-shaft, and *Bore-hole Bar-3* an inclined shaft directed N 17 E at an angle of 45°. Both these bore-holes soon entered the fault zone consisting of blocks and fragments of limestone, siderite and shale below the level of Lower Barbara, and then entered fresh shale.

The open-cast was in limonite ore, the Upper Barbara adit is partially oxidised siderite and ankerite (Braunspat), while the Lower Barbara adit is in a completely fresh primary zone.

The mineralised horizon of limestone or dolomitised limestone is interstratified in shale. The limestone is partially ankeritised and sideritised, but the ore-bearing forms are unusually irregular and the iron content variable, as may be seen from the analyses quoted and Fig. 3. The limestone, and hence the ore bed, runs NNW-SSE, with a very steep dip to WSW. In its thickest parts the ore body is up to 10 m wide, on average 5–10 m, although it has thicker parts of 15–20 m., tapering laterally, however, very rapidly down to 1 m. The Fe content is highest in the thicker parts of the deposits, i.e. in the zone of the siderite components, considerably lower in the thinner parts, where the ore is ankeritic.

there is also totally unmodified limestone. The ore body is intersected laterally by a fault running NNW-SSE and dipping westwards, which brought an end to the ore 12 m below the level of Lower Barbara adit, i.e. at level +185 m. The total overhead height was thus about 50 m.

Chemical analyses of ore from the Barbara field

The analysis of ankerite dates from 1910 (Reuter-Papp, 1919): 9.02% SiO_2, 35.45% FeO, 10.68% CaO, 3.79% MgO, 2.20% MnO, 35.97% CO_2 and heat loss 0.14% S and 2.77% Al_2O_3 = 100.02%. Recalculation gave the following: 9.02% SiO_2, 2.77% Al_2O_3, 0.14% S, 57.16% $FeCO_3$, 19.06% $CaCO_3$, 7.92% $MgCO_3$, 3.57% $MnCO_3$, = 99.58%. Ankerite: 65.17% $FeCO_3$, 21.7% $CaCO_3$, 9.03% $MgCO_3$, 4.07% $MnCO_3$.

There is an analysis of the quartzitic limonite from the Barbara open-cast site dating from 1940 and carried out by Eng. Vinčić (Tućan, 1947): 21.64% SiO_2, 2.86% Al_2O_3, 0.14% CaO, 0.004% MgO, 61.85% Fe_2O_3, 1.60% MnO, 0.001% S, 0.059% P, 10.80% heat loss + CO_2 = 98.95%.

Table 4

Analyses of ore samples from the Barbara underground works

No	Fe	SiO_2	No	Fe	SiO_2	No	Fe	SiO_2	
1	28.81	10.58	16	24.70	–	31	22.63	11.21	
2	39.67	10.30	17	8.96	24.42	32	26.32	18.11	
3	17.00	12.79	18	27.48	8.74	33	10.55	22.45	
4	26.77	16.96	19	24.60	8.97	34	21.37	16.50	
5	9.30	28.59	20	28.63	12.36				Mn
6	27.80	7.74	21	24.50	25.28	21a	25.83	20.96	1.29
7	25.50	9.92	22	14.97	13.77	22a	9.57	3.98	0.61
8	9.65	12.03	23	20.76	15.60	23a	12.61	6.80	1.21
9	18.31	–	24	24.13	9.01	26a	41.29	4.76	1.90
10	9.94	9.37	25	25.27	–	27a	40.23	2.74	1.56
11	3.83	12.65	26	8.04	21.77	28a	2.92	13.62	0.34
12	9.93	20.48	27	9.65	12.77	29a	11.43	14.16	0.69
13	14.51	36.76	28	7.98	11.16	No 1–15 Lower Barbara adit			
14	23.32	20.36	29	9.39	10.96	No 16–34 Upper Barbara adit			
15	9.99	–	30	35.85	11.55	No 22a–29a Barbara underground works			

Average analysis: Lower Barbara adit = 18.29% Fe 16.04% SiO_2
Upper Barbara adit = 19.78% Fe 14.98% SiO_2
Underground = 20.55% Fe 9.57% SiO_2 1.09% Mn

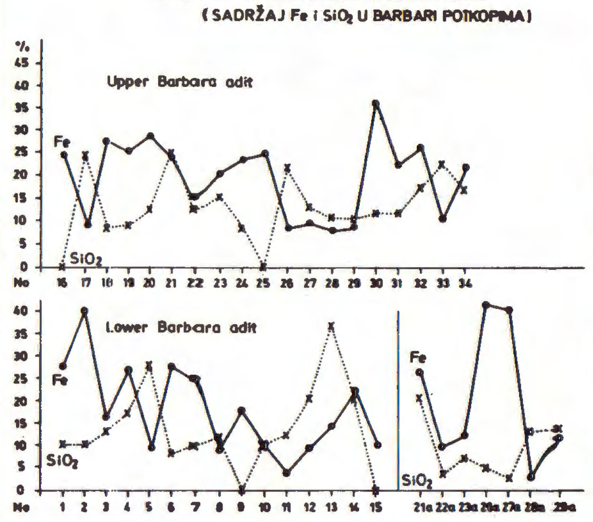
Table 5

Analysis of ore samples from the bore hole Barbara 1 (vertical)

Depth	26.0–27.2	27.2–29.0	29.1–30.3	33.9–35.0	37.0–41.2	41.2–41.8	41.8–46.5	average
Fe	29.55	29.90	36.16	28.03	28.41	29.20	37.04	31.18%

The analyses shown in Table 4 relate to those parts of the Barbara ore field regarded by former miners as unsuitable for exploitation either because of inferior iron content or excessive quartz content, or for both these reasons. The average values for all 15 analyses in the Lower Barbara adit are 18% Fe and 16% SiO_2, while for Upper Barbara they are 20% Fe and 15% SiO_2, very similar values. Even specially selected samples in the underground workings gave average values of 20.5% Fe and 9.6% SiO_2. At any rate, the abandoned sectors of the Barbara ore field are marked by relatively high quartz content, and an iron content of less than 30%. A more detailed scrutiny of the analyses that have been carried out leads us to the conclusion that in the remaining ore body of the old workings we may distinguish between: (a) weakly ankeritised limestones (from 11 analyses) with average values from 8.44% Fe and 16.42% SiO_2; (b) ankeritised limestones (from 5 analyses) with average values of 15.07% Fe and 21.44% SiO_2; (c) ankerites (from 10 analyses) with 23.68% Fe and 14.73% SiO_2; (d) ankerite-siderites (from 6 analyses) with 27.64% Fe and 12.41% SiO_2 and (e) two samples with 35.85% Fe and 11.55% SiO_2 and 39.67% Fe and 10.30% SiO_2 respectively, which corresponds in the first sample to 74.37% $FeCO_3$ component, and 82.29% $FeCO_3$ component in the second sample. Having added in $CaCO_3$, $MgCO_3$ and $MnCO_3$ components, as is the case in other districts of Trgovska Gora, and eliminating the SiO_2 component from the recalculation, it emerges that we are dealing with a siderite ore. The same applies to the analyses nos 26a and 27a, but with 41.29% and 40.23% Fe respectively.

Fig.(Sl.)4. IRON AND SILICA CONTENTS IN THE UPPER AND LOWER BARBARA ADITS (SADRŽAJ Fe i SiO_2 U BARBARI POTKOPIMA)



From the above we may conclude that the old miners extracted siderites and ankerite-siderites with an average content of 10% SiO_2. The ore contained minimal amounts of sulfides, mostly chalcopyrite.

Analyses of the cores from the vertical surface bore-hole Bar-1 at level +236 m, which was 46.5 m deep and reached level +189.5 m, about 8 m below the level of the Lower Barbara adit showed that only two types of ore would be worth exploiting: the first with 28–29% Fe, or ankerite-siderite ore, and the second with 36–37% Fe, or siderite ore.

The Ilića potok mine (no 49)

Early exploratory workings are located about 180 m south-east of the entry to the Lower Barbara adit, downstream on Ilića potok towards its entry into the Velebit potok. According to Zloch (1897) prospecting was conducted at three sites. One of these workings in the form of an incline at level +180 m intersected a siderite body 1 m thick, but prospecting was not continued.

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Željezna rudna ležišta u području Kosna, Trgovska gora, Hrvatska

I. Jurković

Područje Kosna nalazi se zapadno od sideritsko-bakarnih ležišta Gradski potok, Katarina i Svinica, sjevernije od donjeg toka Velebitskog potoka. Izgrađeno je od gornjopaleozojskih šejlova, siltita i grauvaka s mjestimičnim uloščima vapnenaca i dolomitičnih vapnenaca. Serija sedimenata ima generalno pružanje NW–SE s padom od 40–60° na SW. Na sl. 1 ucrtani su položaji opisanih rudnih ležišta: Vinogradina (br. 42), Julius (43), Kosna (44, 45 i 46), Barbara (47, 48) i Ilića potok (49). Rudne pojave su povremeno istraživane i djelomično eksploatirane od 1768. do 1952. god.

U ležištu *Kosna Vinogradina* (42) vadio se manje ili više kvarcovit limonit dnevnim kopom. Nastavak radova u dubinu potkopima je napušten, jer su poremećaji uslovili nestanak rudne pojave.

Površinski dijelovi ležišta *Julius* (43) sastojali su se od kvarcovitog limonita nastalog oksidacijom siderita, a niži dijelovi otvoreni potkopima i niskopima od bakronosnog siderita. Rovna ruda je davala oko 5% Cu. Zbog smanjenja debljine ležišta dubinom kao i sve nižim sadržajem bakra radovi su napušteni. Mikroskopska analiza je pokazala da se primarna ruda sastoji od krupnije zrnatog siderita (Braunspat) zahvaćenog procesom hematitizacije, značajne količine kvarca te uprskanja halkopirita kao glavnog sulfidnog minerala uz manje količine pirita i sfalerita.

Rudnik *Kosna* (44, 45, 46) je otvorio rudnu pojavu s dnevnim kopom i tri dublja horizonta vertikalnog rastojanja od 75 m. Oksidaciona zona, zbog povoljne konfiguracije terena bila je duboka 50 m i iz nje se vadio kvalitetniji limonit s prosječno 10% SiO_2, dok su jače kvarcovite partije ostale neotkopane. Sadržaj Fe u rovnoj rudi (Tabela 1) kretao se od 45,70 do 62,04%, a SiO_2 od 3,70 do 11,34%, sadržaji istih komponenata u vanbilansnoj rudi bili su znatno nepovoljniji. Istraženi dio primarne sideritne zone bio je 25 m po vertikali. Na sl. 2. prikazana je geološka snimka potkopa Donja Kosna. Orudnjenje je konkordantno uloženo u seriju gornjopaleozojskih sedimenata, zahvaćeno je tektonskim poremećajima, a sulfidna mineralizacija je vrlo nepravilno raspoređena unutar kvarcovitog siderita (Tabela 3). Obzirom što je debljina rudne pojave u potkopu Donja Kosna u odnosu na potkop Srednja Kosna smanjena, a sadržaj bakra pao ispod 3% i bio sve nepravilnije raspoređen daljnji radovi su prekinuti pogotovo što je plitko okno dalo negativne rezultate. Rovna ruda između potkopa Donja i Srednja Kosna vađena s tri uskopa nagiba 70° davala je od 3–11% Cu. Mikroskopska analiza rude je identična onoj u Juliusu.

Rudnik *Barbara* (47, 48) nalazio se na sjevernim padinama potoka Ilića, u SE nastavku lokacije Kosna, a sastojao se od dnevnog kopa i dva niža potkopa (sl. 3). Orudnjenje je istraženo oko 50 m po vertikali, od čega gornja polovica u oksidacionoj zoni s kvarcovitim limonitom i niži dio u primarnoj zoni s vapnencima, ankeritima i sideritima. Ukupno je povađeno oko 50.000 t rude. U primarnoj zoni vađen je samo siderit, dok su anketizirane partije i vapnenci ostali u potkopima. Povađeni dijelovi su vrlo nepravilnih oblika, u prosjeku 5–10 m široki, inače u rasponu od 1 m pa do 15–20 m. Sadržaj Fe je najpovoljniji u najdebljim i središnjim dijelovima ležišta. Na tabelama 4 i 5 prikazani su rezultati brojnih analiza uzoraka uzetih 1952. god. kad su obnovljeni istražni radovi. Te analize potječu od uzoraka onih dijelova mineralizirane zone koju su raniji rudari ostavljali bilo zbog previsokog sadržaja SiO_2 ili preniskog sadržaja željeza. Od sulfidnih minerala uočene su neznatne količine halkopirita i pirita. Tri bušotine, jedna s površine i dvije iz potkopa Donja Barbara utvrdile su prekid dubinskog prostiranja mineralizacije zbog vrlo jake rasjedne zone. U jezgrama bušotine Bar-1 utvrđene su dvije

jače mineralizirane partije unutar vapnenaca, slabija s 28–29% Fe (ankeriti) i kvalitetnija s 36–37% Fe(kvarcoviti sideriti i ankerit-sideriti) (tabela 5). U donjem toku *potoka Ilića* nalazili su se istražni radovi manjih razmjera na siderite s vrlo malo rudnih sulfidnih minerala.

Rudne pojave područja Kosna paragenetski i genetski su identične ili vrlo slične orudnjenju u područjima Gradski potok, Svinica i Katarina. Pretežno su to slojna rudna ležišta, konkordantno uložena u šejlove i grauvake, pojava u Barbari vezana je za uložak vapnenaca unutar šejlova i siltita. Svi tektonski poremećaji u jednakoj se mjeri reflektiraju na rudne pojave i okolne stijene. U prvim fazama razvoja tih rudnika eksploatirale su se kvalitetnije partije limonita, a kasnije iz dubljih primarnih zona ili bakarna ruda ukoliko je srednji sadržaj rovne rude imao 5 ili više procenata bakra, odnosno željezna sideritna ruda s 10% ili manje SiO_2.